Original article

Performance profile for ILCA class elite sailors. Differences between men and women

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Summary

In sport sailing, there are three fundamental pillars of performance for dinghy sailors (physical condition, cognitive ability and equipment). One of the decisive moments in a single-handed dinghy race is sailing upwind, as it requires a high physical demand from the sailors to keep the boat flat and make the best decisions according to the tactical conditions of the race. The objective of the research is (i) to analyze the performance of elite sailors on the hiking position in a dynamic virtual sailing situation and (ii) to measure the lower body muscle fatigue in the hiking action. The sample consisted of 10 sailors from the Ilca sailing class and belonging to the Olympic teams of the Norwegian, Mexican and Spanish national teams, 6 of them men (M_{age}=31.67, SD_{age}=6.861) and 4 women, (M_{age}=30.50, SD_{age}=4.655). The fatigue protocol consisted of a static test and a dynamic test of the sac body position. Both tests measure the sailors' effort up to extreme fatigue or loss of position. The test was performed on the vSail-Trainer® sailing simulator, which allows to reproduce real sailing conditions and displays data on boat control variables. The results obtained show statistically significant differences between the group of women and men on boat speed (P=0.039), distance sailed (P<0.001) and hiking effort (P=0.002). There are statistically significant differences in lower body power pre and post fatigue test. This does not lead to the conclusion that the simulator is a valid tool to assess fatigue specifically in Ilca class sailors.

Key words:
Olympic sailors. Ilca class. Fatigue test. Sailing simulator.

Perfil de rendimiento de regatistas de élite de clase ILCA. Diferencias entre hombres y mujeres

Resumen

En la vela deportiva, tres son los pilares fundamentales del rendimiento de los regatistas de vela ligera (condición física, capacidad cognitiva y material). Uno de los momentos determinantes en una regata de vela ligera individual es la navegación en el rumbo de ceñida, ya que requiere de los regatistas una alta demanda física, para llevar la embarcación plana y tomar las mejores decisiones según las condiciones tácticas de la regata. El objetivo de la investigación es (i) analizar el rendimiento de regatistas de élite sobre la posición de sacar cuerpo en una situación dinámica de navegación virtual. (ii) medir la fatiga muscular del tren inferior en la acción de sacar cuerpo. La muestra fueron 10 regatistas de la clase Ilca de navegación y pertenecientes a los equipos olímpicos de las selecciones nacionales de Noruega, México y España, 6 de ellos hombres (M_{edad} =31,67, SD_{edad} =6,861) y 4 mujeres, (M_{edad} =30,50, SD_{edad} =4,655). El protocolo de fatiga estuvo compuesto por un test estático y un test dinámico de la posición de sacar cuerpo. Ambos test miden el esfuerzo de los regatistas hasta la fatiga extrema o hasta perder la posición. El test se realizó en el simular de vela vSail-Trainer®, el cual permite reproducir condiciones reales de navegación y muestras los datos sobre variables de control de la embarcación. Los resultados obtenidos muestran diferencias estadísticamente significativas entre el grupo de mujeres y hombres sobre la velocidad de la embarcación (p =0,039), distancia navegada (p <0,001) y *hiking* (p =0,002). Existen diferencias estadísticamente significativas en la potencia del tren inferior pre y post test de fatiga. Esto no lleva a concluir que el simulador es una herramienta válida para valorar la fatiga de forma específica en regatistas de clase Ilca.

Palabras clave:
Regatistas olímpicos. Clase Ilca. Test de fatiga. Simulador de vela.

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Introduction

In competitive sailing, there are three fundamental aspects to dinghy sailors' performance. Firstly, the material that is used in competition, such as the vessels and the sails. Secondly, the sailors' cognitive skills, such as the ability to understand and predict weather conditions, the capability for tactics and technique at each moment of the race. Finally, the sailor's physical ability, such as strength, muscle power and aerobic and anaerobic capacity[1,2]. These three determining performance factors have changed over time, mainly the sailors' physical and cognitive skills, due to the current level of competition.

If we focus on this latter aspect, the sailors' physical capacity is the area of performance most studied to date, with over 50% of research focussed on aerobic, anaerobic, muscle strength, strength, power, Heart Rate (HR) or body composition, among others[3-7]. Most of this research looks at dinghy sailors, using single- or double-handed vessels. However, the same physical requirements are not required of sailors in all of them. This is why the types of vessels should be differentiated plus the demands for each of them[7,8]. Six classes competed at the last Olympic games (Tokyo 2021), in men's, women's and mixed categories. Out of these vessels, it should be mentioned that 1 is windsurf, thereby competing on a board, 3 are double-handed vessels and 2 are single-handed vessels. There are classes where the classifications are different for men and women, as the sail sizes adjust to each gender (male and female), and the sail is smaller for women, as happens in the ILCA and RS-X classes. In other classes such as the 470, classifications are different for men and women, but the vessel is the same, with no difference in the sail surface area. Most research found so far on Olympic class sailors uses single-handed boats as they require sailors to combine cognitive and physical skills. This does not usually happen in double-handed vessels, where one of the crew is usually more physical and the other has better cognitive skills and makes decisions[9,10].

One of the determining moments in an individual dinghy race is sailing on a close-hauled course, as it is physically demanding on the sailors to keep the vessel flat and to make the best decisions according to the tactical race conditions[11]. This race situation produces the most physically demanding action which is the hiking position. For the sailors to make the vessel move as hydrodynamically as possible (flat), they must take their centre of gravity as far as possible from the boat's centre line, merely using the strap in the centre of the vessel which supports the arch of both feet. Many research projects have looked at leaning-out in static situations[12-14], where the crew must remain in this fully extended position for as long as possible. Over time, it has been demonstrated that, in real sailing situations, this position is dynamic, not static, during sailing, where the crew perform a balancing movement, to synchronise the heel of the boat, with the gusts of wind, the waves and/or the presence of other vessels[15].

Simulators have been used for this reason and due to the difficulties of measuring sailors' performance during this technical action. Simulators used to date have evolved from static benches, which are not the same size as a real vessel[12-14], up to semi-submersible simulators that simulate various wind conditions, with the dimensions of a real boat[9,15-17].

In this regard, this research uses a semi-submersible sail simulator, which represents real sailing conditions in a laboratory-controlled environment, thereby making it easier to measure fatigue indicators in the implicated muscles, directly after performing the action. Consequently, this research aims to provide a reliable tool to measure topflight sailors' performance. The aim of the research is to (i) analyse elite sailors' performance over the hiking or leaning-out position in a dynamic virtual sailing situation. (Ii) measure lower body muscle fatigue in the leaning-out action. (Hi) Men will have greater sailing performance than women in terms of sailing speed and hiking variables. (Hii) After the test, the lower body power will drop in both sexes, and it can be affirmed that the tool is valid to measure fatigue in a specific sailing situation.

Material and method

Sample

The sample for this research was made up of 10 sailors from the former Laser class and the Ilca sailing class. They all belong to national Olympic teams, for Norway, Mexico and Spain, 6 were men, with M_{age} = 31.67, SD_{age} = 6,861 and 4 women, with M_{age} = 30.50, SD_{age} = 4,655. Table 1 shows the anthropometric values for both groups. They had all participated in international races in world championships and pre-Olympic races.

The ethics committee from the lead author's university authorised the research (reference number for the institutional review board CE021912). All applicable institutional standards were followed relating to the ethical use of human volunteers (such as the Declaration of Helsinki). Informed consent was obtained in writing from all participants, who were informed exhaustively about the study.

Table 1. Body composition descriptors.

	Men's group			Women's group		
	N	Average	SD	N	Average	SD
Age	6	31.67	6.86	4	30.50	4.65
Weight	6	81.88	2.18	4	61.52	3.39
Height	6	182.17	6.01	4	167.00	3.74
BMI	6	24.82	1.81	4	21.85	0.85
% fat	6	14.03	4.18	4	18.40	1.40
% water	6	63.53	1.56	4	61.08	0.37
Muscle mass	6	68.07	1.81	4	47.95	5.63
Bone mass	6	3.55	0.10	4	2.60	0.18

Procedure

The fatigue protocol comprises two parts: a static test and a dynamic test. Before carrying out the protocol, the yachtsman will run a familiarisation protocol with the simulator, to eliminate the learning component from the performance. This was followed by muscle activation, to prepare the crew for a sub-maximal effort. After a warm-up, and before and after the fatigue test, the sailors performed 2 counter movement jump tests (CMJ).

The sailors chose their preferred side to perform the test, as the dinghy can be sailed either side. All the sailors chose to perform the test on the starboard side (Figure 1). As the literature confirms, the sailors obtain better performance by sailing on the starboard side rather than port[18].

The first test was an isometric test (quasi-isometric) where the simulator was stopped, permanently tilted 5 degrees and fixed as such. The sailors had to grab the sheet and the tiller and hold the hiking position for as long as possible. The test finished when the sailor lost their initial position. This aims to achieve a point of reference for maximum performance.

The second test was performed in a dynamic sailing simulation situation with a wind intensity of 16 knots. The men sailed with the Ilca 7 dinghy sail dimensions and the women used the Ilca 6 dinghy size, as in real situations. They were asked to keep the boat on a close-hauled course for the whole time, with the boat flat or as flat as possible, to maintain maximum performance. To get greater implication from the sailors, the boat's velocity indicator was fitted, asking them to follow this course as fast as possible until reaching maximum fatigue.

Figure 1. Sailors performing the strength test.

Instruments and variables

The muscle power test using the CMJ jump was performed on a contact platform (Chronojump® DNI-A1). This instrument provided the lower body power values and jump height.

The strength test was performed on the sail simulator (vSail-Trainer®), designed by the Virtual Sailing Pty Ltd company, the VSail-Trainer®. The simulator comprises two parts. The first is the hardware, made up of the vessel cockpit and a laptop. The computer controls the second element of the simulator, which is the software for the virtual simulation, the sailing conditions, the projection and the sound of the simulated situation. The cockpit comprises a boat hull, an electronic system and a hydraulic arm. The electric system controls the hull, which is connected to the computer that controls the sailing conditions (wind and intensity). The cockpit was the same as the Ilca vessel, which helps the simulator reproduce the sailor's real situation movements. The simulator works like a real boat, with a tiller to control the course/direction and a sheet to control the main sail. The simulator reproduces the boat's list angle, which means that the sailors have to continually adjust their position in relation to the heeling. The size of the image projected was 2.00 m x 2.50 m for this study, to reproduce real dimensions[19].

The variables evaluated with the simulator were as follows:

- Isometric time: this refers to the number of seconds that the subjects could maintain the hiking position during the static test, where they must maintain the isometric position.
- Dynamic time: this refers to the number of seconds that the subjects could maintain the hiking position during the dynamic test, where they must sail as fast as possible in the close-hauled course, maintaining the hiking position.
- Total distance sailed: number of metres sailed during the test,
- Speed: average speed sailed during the test, measured in knots.
- Hiking: average force exerted during the action of taking the body out during the test, measured in Newtons.
- Point of sail: the average angle of the vessel against the direction of the wind. As this is a sailing test on a close-hauled course (45º), they must stay as close as possible to this point of sail.
- Heeling angle: average value of the vessel hull's lateral angle during the test. This angle is counteracted by the force exerted to lean out or hike.
- Tiller variability: midpoint value of the degrees of variation made by the sailors on the tiller. The larger the angle, the more resistance the tiller gives to the vessel displacement.
- VMG: (Velocity Made Good): understood to be the optimum velocity of the vessel in relation to the course, expressed in knots. The higher the VMG, the greater the performance.

Statistical analysis

The IBM SPSS v.24.0 statistics programme was used to analyse the data. Preliminary tests were run on suppositions to check that the variances were homogeneous, and the variables were normal. The Levene and Shapiro-Wilks tests were carried out to confirm the suppositions of variance and normality, respectively ($p > 0.05$).

The averages and the standard deviations were calculated for all study variables, for each group (men and women). To compare the differences between the groups, a t-test was performed for independent samples (male group and female group). To compare the differences in lower body power variables pre and post test, the t-test was performed for related samples on both groups, before and after the dynamic sailing test. The level of statistical significance was set as $p < 0.05$ (confidence interval of 95%).

Results

The results for the sailing variables do not demonstrate statistically significant differences between men and women over time or duration of both tests (dynamic and isometric). On the contrary, statistically significant differences are found over the distance sailed ($p < 0.001$), velocity ($p = 0.039$), hiking ($p = 0.002$) variables during the performance of the dynamic test, where the results of these three variables were higher among men than women (Table 2).

Regarding the jump power and jump height results before and after dynamic sailing, we find statistically significant differences between the pre-test and post-test for the jump power variables ($p = 0.02$) and the jump height ($p=0.005$) in the group of men (Table 3). The results are lower in both variables after carrying out the dynamic sailing test.

Similar results are seen for the group of women, obtaining statistically significant differences between the pre-test and post-test for the jump power variables ($p = 0.006$) and jump height ($p = 0.001$). The results for both variables are lower after the dynamic sailing (Table 4).

Discussion

Taking into account the objectives set out in this research, (i) analyse elite sailors' performance in the hiking position in a dynamic virtual sailing situation. (Ii) measure lower body muscle fatigue in the leaning-out action.

Concerning the first objective and due to adjusting the sail surface area on the ILCA 7 vessel (men) and 6 (women), we consider that there are no differences in the performance of male and female elite sailors. The results show differences in the sailing test between men and women in 3 sailing variables: total distance sailed, sailing velocity and hiking mean, where the results are greater in the group of men over all three variables. The performance in these three variables is interconnected, as greater hiking means that the boat sails flat, generating less resistance with the water (hydrodynamic) and consequently higher velocity[20-23]. We might think that the heeling could be affected by the effort made during the hiking action and the wind intensity[24,25]. However, in this case, as we have data on the vessel's heeling angle, we can see that there are no statistically significant differences between the result for men (4.28 ± 2.37) and women (4.17 ± 1.65). Consequently, it is not a matter of hydrodynamics as both groups have the same heeling. We

Table 3. Descriptors for the strength and power test among men.

	Men's group pre		Men's group post		p	Average difference
	Average	SD	Average	SD		
Power	3,879.5	235.78	3,704.2	138.74	0.020	175.33
Height	36.0	4.10	32.3	2.94	0.005	3.67

Table 4. Descriptors for the strength and power test among women.

	Women's group pre		Women's group post		p	Average difference
	Average	SD	Average	SD		
Power	2,656.8	282.10	2,451.0	303.06	0.006	205.75
Height	30.0	2.58	26.5	2.65	0.001	3.50

Table 2. Sailing variables descriptors.

	Men's group			Women's group			p	Average difference
	N	Media	DS	N	Media	DS		
Isometric time (s)	6	207.00	48.175	4	178.50	31.395	0.331	28.500
Time in dynamic (s)	6	363.83	31.410	4	344.25	77.629	0.587	19.583
Total distance sailed (m)	6	1,144.74	37.131	4	896.86	81.448	<0.001	247.876
Velocity (kn)	6	6.24	0.496	4	5.36	0.63	0.039	0.878
Hiking (N)	6	1,590.78	114.74	4	1,173.36	180.94	0,002	417.422
Sailing angle (º)	6	53.89	3.24	4	50.09	1.84	0.069	3.804
Heeling angle (º)	6	4.28	2.37	4	4.17	1.65	0.942	0.104
Tiller variability (º)	6	2.94	1.48	4	4.31	0.34	0.114	-1.370
VMG (kn)	6	3.65	0.25	4	3.33	0.18	0.063	0.325

believe that the hiking difference is due to the greater sail surface area on the men's boat, so the effort to maintain the minimum heel during closehaul must be greater for the men than the women. In this respect, it is worth considering that the men do not present greater strength in relative values than the women. Therefore, the first study hypothesis is partially confirmed, taking into account the latter insight.

Regarding the sailing velocity variable, we can see that the men are capable of sailing faster than the women and so this makes them sail further. This might be due to trimming the sheet. During close-hauled sailing, the crew have the sail's telltales, which indicate their optimum trim. In this respect, during the sailing test, if the group of women did not have optimum closing or as close to the optimum as the men's group, this might be due to fatigue. This fatigue can take place in two different ways. (i) that, due to physical fatigue, if the sail is closed in optimum conditions, the boat will heel by more degrees and the sailor is incapable of continuing to hike to obtain the best performance, so they ease the sail by a few centimetres, losing velocity, but maintaining the minimum heel that they can control with muscular fatigue[15,26,27]. (ii) that due to physical fatigue, the sailor experiences cognitive fatigue meaning that they cannot focus on the telltales (places with relevant information) and they lose velocity in line with their loss of attention on the location that provides relevant information[9].

In response to the second objective, to measure muscular fatigue of the hiking action, the CMJ test was used before and after the dynamic sailing test, which takes participants to maximum fatigue. We can see that, in both the men's and women's group, there are statistically significant differences between the pre-test and the post-test for the jumping power and jump height variables. These results demonstrate that this dynamic sailing test takes the sailors to a real fatigue situation in the close-hauled course, when reproducing sailing conditions that require the hiking technique. Until now, simulators have not reproduced realistic sailing conditions that assimilate the test with a real situation[18,28]. The results demonstrate that in a simulated situation this sailing test is a tool that really produces muscular fatigue in the main musculature implicated in the hiking technique, thereby confirming the second study hypothesis. Consequently, we defend that, henceforth, for sailors, the strength tests in a similar situation to their sailing situation, leaving behind bicycle ergometer tests or treadmills, are unspecific for this type of population.

Conclusions

After review and discussion of the results, we can conclude that the fitness of the male and female sailors in the Ilca class is a determining factor for the dinghy performance. Although the differences between them are not physical when achieving maximum performance, as shown by the boat's control variables, we consider that fatigue affects cognitive capacity, which can determine differences in performance, in other words, fatigue tolerance.

On the other hand, we consider the simulator as a valid tool to assess fatigue specifically among sailors in individual classes, where the hiking position determines sailing performance. The simulator can adjust to the class of vessel and the weather conditions encountered in real situations.

Study limitations

The study is limited by a very small population, despite being Olympic level sailors, the statistical analysis can be affected by the small number of subjects being analysed.

It would be very interesting to run this test at different points in the season, as the sailors' fitness will affect their performance in the sailing test.

Conflicts of interest

The authors declare that there is no conflict of interest.

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